

Total to central luminosity ratios of quiescent galaxies in MODS as an indicator of size evolution

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Abstract. Using the very deep Subaru images of the GOODS-N region, from the MOIRCS Deep Survey and images from the HST/ACS, we have measured the Luminosity Ratio (LR) of the outer to the central regions of massive ($M > 10^{10.5} M_{\odot}$) galaxies at fixed radii in a single rest-frame for $z < 3.5$ as a new approach to the problem of size evolution. We didn't observe any evolution in the median LR, Had a significant size growth occurred, the outer to central luminosity ratios would have demonstrated a corresponding increase with a decrease in redshift.

1. Introduction

The galaxy size is an inevitable part of any model of galaxy evolution, therefore observationally determining its evolution in the last ~ 12 Gyrs ($z \sim 3.5$) will play a significant role in constraining the current models. As a review of some of the most recent studies; Daddi et al. (2005) found that 4 of 7 massive passive galaxies at $z > 1$ showed very small effective radii. Damjanov et al. (2009) claimed that there are no local counterparts to those compact objects. As a recent example Cassata et al. (2011) found a 5 times number density increase in higher redshifts and a 0.5dex size increase. From a different perspective, van Dokkum et al. (2009) found a high velocity dispersion compact galaxy at $z = 2.186$.

The results above were not left unchallenged tough and Cenarro & Trujillo (2009) and Cappellari et al. (2009) failed to find any significant increase in the velocity dispersion. In a very interesting discovery, Valentinuzzi et al. (2010) found a significant number of compact early type galaxies in the local universe and found similar number densities to those claimed for the highredshift compact galaxies, following those results, Saracco et al. (2010, 2011) show that the number density of compact massive ETGs has stayed constant in the past 10 Gyrs. In a recent study, Ichikawa et al. (2012)(in press) showed that a universal mass-size relation exists and that it is independent of redshift and slope.

The majority of these studies use the effective radii that is strongly vulnerable to the object's outer regions, we believe that at least one of the reasons of such contrasting results can be in this vulnerability, so in this paper and the subsequent (Akhlaghi et al. 2012, in preperation; here after A12) we will try to approach this problem from another point of view that will be further elucidated in §3. In this paper the WMAP 7-year results

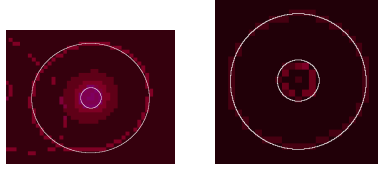


Figure 1. Concept of Luminosity Ratio (LR) shown for two sample galaxies, the outer aperture is SExtractor’s MAG_AUTO and the inner one MAG_APER set equal to 2.6kpc for the corresponding redshift. Left: A galaxy at $z \sim 2.04$ with mass $1.7 \times 10^{11} M_{\odot}$ with a V band 2.6kpc LR of 3.88. Right: A galaxy at $z \sim 2.89$ with mass $1.15 \times 10^{11} M_{\odot}$ with a V band 2.6kpc LR of 2.37.

(Komatsu et al. 2011) are used for the cosmological constants: $H_0 = 70(\text{km/s})/\text{Mpc}$, $\Omega_{\Lambda} = 0.73$ & $\Omega_M = 0.27$.

2. Data

In this analysis we have used the J, H & K_s images from the Multi Object Infra Red Camera and Spectrograph (MOIRCS, Suzuki et al. 2008), installed on the Cassegrain focus of the Subaru telescope and B, V, r & i images taken with HST/ACS. Detailed information regarding the reduction and analysis of the images and compilation of the catalog used here has been elaborated in Kajisawa et al. (2011), hereafter K11. In this study we have only used the wide image and catalog results of MODS which show 5σ errors in one arcsecond diameter of $25\text{mag}/\text{arcsec}^2$ in the K_s band. It has been shown in K11 that this catalog is 85 ~ 90percent complete at 25 magnitudes and so all the objects with K_s band total magnitudes more than this value were removed from this analysis. Being the largest PSF value, all the images were PSF-matched to 0.6. SED fitting to obtain the observed mass and photometric redshift of the objects was performed with the multiband photometry of the images explained above along with $3.6\mu\text{m}$, $4.5\mu\text{m}$ & $5.8\mu\text{m}$ images from Spitzer/IRAC. Here we use the results of GALAXEV (Bruzual & Charlot 2003) with a Salpeter IMF (Salpeter 1955). The derived redshift showed excellent agreement with the spectroscopic redshift $\delta z/(1+z) = -0.011$.

3. Analysis

The new parameter used in this study and further elaborated in A12 is the Total to Central Luminosity Ratio (LR). The total luminosity is obtained from SExtractor’s MAG_AUTO, but the central radii is obtained from an aperture photometry with the size of 2.6kpc, which is the maximum physical size of our PSF during the cosmic history. Based on the definition of the effective radii, if $LR = 2$ then then $r_e = 2.6\text{kpc}$ and independent of the galaxy morphology, if $LR > 2$, then the effective radius is larger and if $LR < 2$ then the effective radii is smaller than that chosen value. The images were not deconvolved due to the simple reason that it adds to the noise we are trying so hard to avoid.

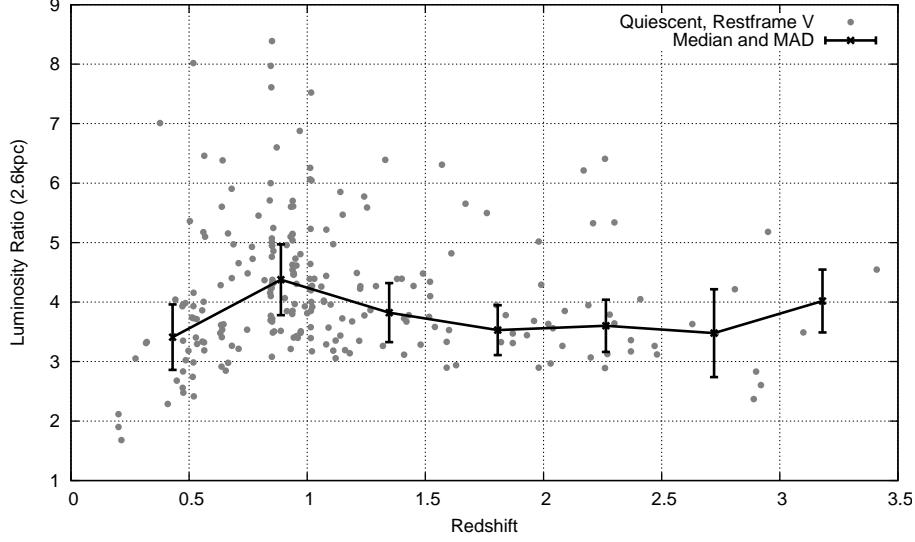


Figure 2. Rest frame V band Luminosity ratio evolution for quiescent galaxies in MODS with physical aperture of 2.6kpc. LR for each galaxy is displayed as a gray dot, they are binned in 0.5 redshift bins, points connecting the lines are the median and the error bars are the Median Absolute Deviation (MAD).

In this short paper, we use the Williams et al. (2009) rest-frame color-selection technique to choose quiescent galaxies above $M \approx 10^{10.5} M_{\odot}$. Since the stellar mass of the galaxy can best be represented by the restframe V images, we used the i, z, J, H & K images for the different redshifts.

4. Results & Discussion

232 galaxies satisfied the quiescent and mass conditions we required and were detected by SExtractor in their desired image. LR was calculated for all galaxies with radii: 2.6kpc. The selected galaxies were binned to redshift bins of 0.5 and the median value of each bin was chosen as a representative; Fig. 2. The dispersion is shown with the Median Absolute Deviation (MAD) as the error bars.

The most salient result of Figs 2 is that it is basically a horizontal line and there is very slight variations of LR present. Put simply, Fig 2 shows that the median of the quiescent galaxies in MODS have not undergone any significant size evolution in the last 12Gyrs. Another interesting result that can be inferred from Fig 2 is that except a very low number of galaxies in the local universe, all values of LR(2.6kpc) are larger than 2, this means that all our galaxies have an effective radii larger than 2.6kpc.

In some previous studies that have observed significant size evolution, the average value was chosen as a representative (e.g., van Dokkum et al. 2010). As we see from Figs 2, had we taken the average of the points, due the large dispersion and the outliers present in $z \sim 1$, we would see a much more significant evolution in LR than we see now.

One important caveat of this current study is that the exact limits of our measurements and the exact relation it has with the effective radii have not been tested through simulated galaxies embedded in our noise and PSF. Such simulations and analysis will be fully elaborated in A12.

5. Summary

As a conclusion it can be mentioned that based on a purely phenomenological approach to the problem of the size evolution of quiescent galaxies, and using a new parameter to study this evolution that will be completely scrutinized in A12, we find that quiescent galaxies in GOODS-North have not undergone any significant size evolution in the course of the last 12Gyrs.

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